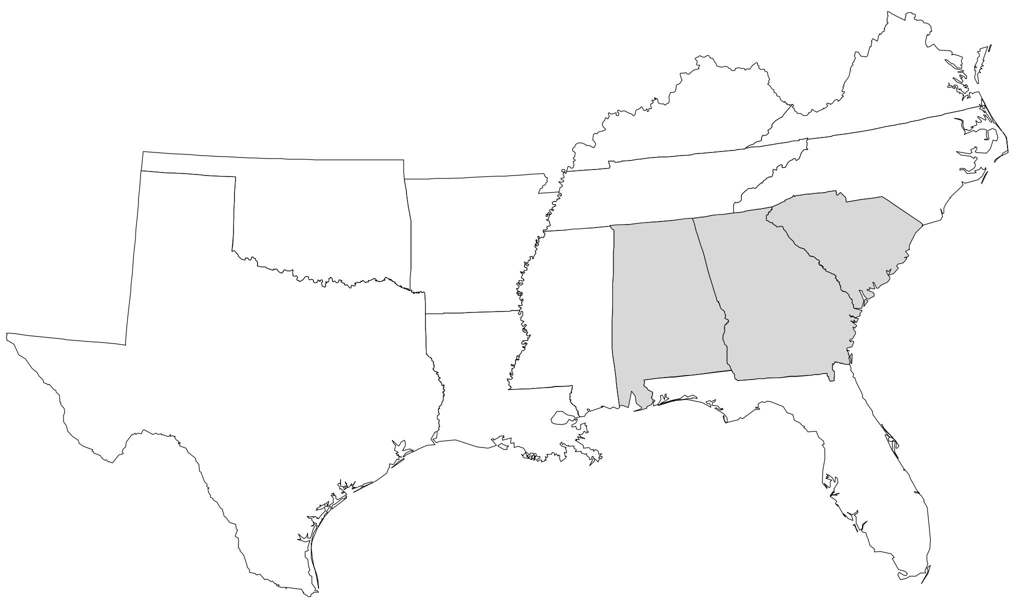
The Southeastern Variant

of the

Forest Vegetation Simulator



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Introduction

The ***Forest Vegetation Simulator (FVS)*** is an individual-tree, distance-independent growth and yield model. ***Suppose*** is the graphical user interface for FVS (Crookston 1997). FVS will simulate growth and yield for most major forest tree species, forest types, and stand conditions. FVS can also simulate a wide range of silvicultural treatments. Variants of FVS provide growth and yield models for specific geographic areas of the United States. The Southeastern variant (Southeast) applies to a portion of the southeastern United States: Alabama, Georgia, and South Carolina.

This document is a technical overview and users guide for the Southeast variant of FVS. This overview describes basic model structure, operation, data format, assumptions, and formulae. This document is not a complete user's guide for FVS, nor does this overview describe the Suppose graphical user interface for FVS.

Prognosis (Stage 1973) is the original model that evolved into the Forest Vegetation Simulator. Stage developed Prognosis for use in the Inland Empire area of Idaho and Montana. In the early 1980s, the National Forest System's Timber Management Staff selected the individual-tree, distance-independent model form as the nationally supported framework for growth and yield modeling. The Timber Staff incorporated much of the Prognosis modular structure and capabilities into the national model framework. This model framework is the ***Forest Vegetation Simulator***, or ***FVS***.

The Growth and Yield Unit of the Forest Management Service Center (FMSC) in Fort Collins, Colorado, maintains, supports, develops, and provides training for FVS. The FMSC performs a technology transfer role, working with researchers and National Forests staff from various geographical areas to incorporate their findings into the FVS framework.

There are currently 21 different FVS variants in production use. Each is calibrated to a specific geographic area of the United States. The FMSC is constantly developing additional variants and improving existing variants.

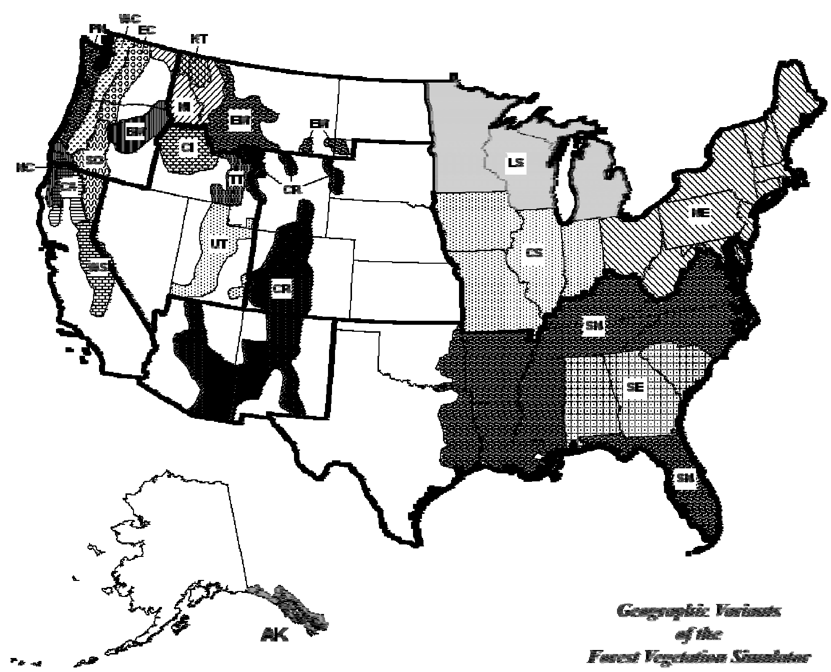

Figure 1. - Geographic Variants of the Forest Vegetation Simulator

The Southeast variant of FVS was first developed in 1996 using equations from the Southeast TWIGS (Southeast TWIGS) model developed by Ralph Meldahl and Roger Bolton of the School of Forestry at Auburn University, Auburn, Alabama. Auburn University, the Forest Resources Systems Institute (FORS), and the Georgia Forestry Commission jointly funded this project (Meldahl and Bolton 1989). The Southeast TWIGS model was fit from Forest Inventory and Analysis (FIA) data from Alabama, Georgia, and South Carolina. Meldahl and Bolton used the same methods in developing Southeast TWIGS that they used to develop Georgia TWIGS (Meldahl and Bolton 1990).

CAUTION: The Southeast variant of FVS is most applicable in the same geographical area as Southeast TWIGS: in Alabama, Georgia, and South Carolina. Users outside this geographic area should scrutinize their output to ensure it is appropriate for their area.

All equations used in the Southeast Variant are the same as those used in Southeast TWIGS, unless otherwise noted. Refer to the *Summary of Modeling Efforts for Southeast TWIGS: SouthEastern TWIGS* (Meldahl and Bolton 1989). This paper describes methods, data sources, the analysis, and the growth models of Southeast TWIGS.

Model Structure

The FVS model has several components that work together to simulate forest growth and management actions. There are three main growth components of the FVS: a large-tree model, a small-tree model, and an establishment model; and, there is a mortality model. FVS treats a stand as the population unit, using forest inventories or stand examination data. The “Event Monitor” oversees program execution and processes activities that keywords schedule. Input files include “keywords” that the user can manipulate to simulate different management scenarios (VanDyck 1999). There are extensions for FVS variants to consider the influence of other agents upon tree growth, such as insects and disease. Post-processors are other programs that expand FVS’s capabilities to report and display output.

Model Execution

This section summarizes FVS operation to provide context for the details in this model overview. Figure 2 displays the major execution steps in FVS.

1. FVS begins by reading keywords and the tree record file.
2. FVS computes stand characteristics for the initial year (cycle 0). This is typically the inventory date or the stand regeneration date.
3. FVS backdates all stand attributes to the beginning of the growth period. It “grows” the stand back to the inventory date, compares the values from the actual inventory date with simulated values, and computes scale factor adjustments to account for differences in actual and model values.
4. FVS continues with the steps it repeats every cycle. FVS checks the Event Monitor keywords and functions to see if the user scheduled any activities based on existing stand conditions at the start of the cycle. Afterwards, FVS checks the Event Monitor for scheduled that are based on post-activity conditions within the same cycle. Event Monitor capabilities are powerful and very useful for modeling situations and creating variables not covered in standard FVS output. Crookston (1990) describes Event Monitor functions and processes along with several good examples.
5. If large trees exist in the tree-list, FVS computes their new diameter,

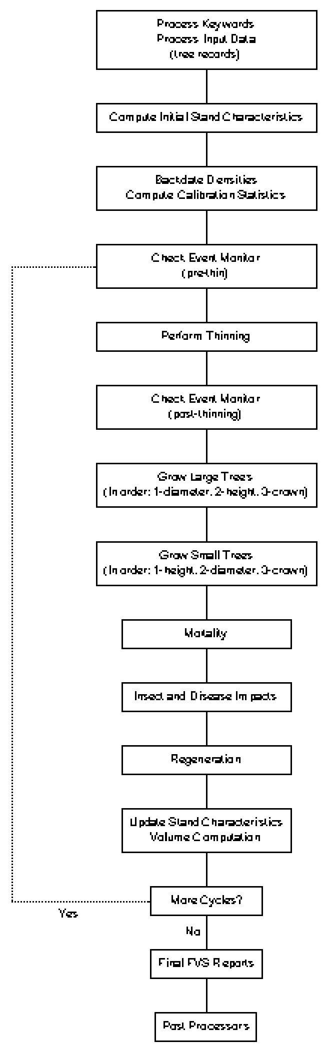

Figure 2. FVS Program Execution

height, and crown relationships one growth cycle into the future (10 years or another user-specified time interval).
6. FVS computes small tree height, diameter, and crown relationships. In all FVS variants, an overlap diameter zone exists between large and small trees. FVS uses a weighting procedure to compute tree height increment to obtain a smooth height-growth transition from small to large tree models.
7. Following growth estimation, FVS computes mortality based on individual tree variables such as diameter and crown ratio, and on stand variables such as maximum basal area.
8. FVS considers the effects from biological change agents such as insects and pathogens, if the variant includes an insect or pathogen extension.
9. FVS adds new seedlings to tree-lists generated in the regeneration step. Some FVS variants have natural regeneration routines, but most variants, including the Southeast Variant, depend on the user to specify the species and number of trees to plant. The Southeast Variant has a stump sprout algorithm, whereby certain species will sprout after a harvest.
10. After projecting the stand one growth cycle, FVS computes, summarizes, and records the remaining attributes, including volume. Per Figure 2, FVS repeats the sequence from Event Monitor check to this point for each cycle.
11. After FVS completes the scheduled cycles, it prints final output reports and generates files needed by post-processors.

Data Codes and Conversions

Data must be coded in the appropriate format for the FVS model. The Suppose interface for FVS also requires certain files for it to set up an FVS simulation. FVS and Suppose use three different types of files. The first file is used solely by FVS, and the second and third are specific to Suppose.

1. FVS Tree Data File (**<filename>.fvs**)
2. Suppose Stand List File (**<filename>.slf**)
3. Suppose Locations File (**<filename>.loc**)

Each has a different file extension. Each of these files contains information about the stand(s) and tree records. Some of the data in these files are coded the same for all of the FVS variants, but other data must be coded specifically for the variant being used. All of the files are simple text files, and may be viewed or edited in a text editor. This section describes these files and the appropriate codes for the Southeast Variant.

FVS Tree Data

Each stand or inventory plot has its own FVS tree data input file. Each tree (or group of similar trees on a plot) has an entry in the file. The minimum required information for a tree data file is the plot number, species, and diameter at breast height for each tree record. In the absence of other data entries, the FVS variants include algorithms to dub in missing information or resort to program defaults. However, there is a specific default format for the tree data. The tree data fields must be in defined columns as described in Table 1. The TREEFMT keyword can be used if the tree data is formatted differently or is located in different columns.

Table 1. – FVS Tree Data File Format

Columns	Data Type	FORTRAN Format	Description
1-4	Integer	I4	Plot identification (i.e., plot number)
1-7	Integer	I7	Tree identification (unique for each tree record).
8-13	Real	F6.0	Tree count (number of sample trees that this record represents)
14	Integer	I1	Tree history code

Columns	Data Type	FORTRAN Format	Description
15-17	Character	A3	Species code (left-justified)
18-21	Real	F4.1	Diameter at breast height (nearest tenth of an inch, outside bark)
22-24	Real	F3.1	Diameter increment (nearest tenth of an inch, inside bark)
25-27	Real	F3.0	Live height (feet)
28-30	Real	F3.0	Height to topkill (feet)
31-34	Real	F4.1	Height increment (nearest tenth of a foot)
35	Integer	I1	Crown ratio code
36-39	Integer	I2,I2	First pair of tree damage and severity codes
40-43	Integer	I2,I2	Second pair of tree damage and severity codes
44-47	Integer	I2,I2	Third pair of tree damage and severity codes
48	Integer	I1	Tree value class code.
49	Integer	I1	Cut or leave prescription code
[The following fields are read only if field 2 of TREEDATA keyword is not blank.]			
50-51	Integer	I2	Plot slope percent code.
52-54	Integer	I3	Plot aspect code.
55-57	Integer	I3	Plot habitat type code.
58	Integer	I1	Plot topographic position code.
59	Integer	I1	Plot site preparation code.

The following describes the tree data file codes for the Southeast Variant:

Plot Identification, Tree Identification, And Tree Count

The first three fields in the tree data file are coded the same with all of the FVS variants. The entries in these fields are described in Table 1, above.

Tree History

Tree history refers to a tree's status in the current inventory. It indicates whether it died during the mortality observation period or before the mortality observation period. In the former case (recent dead), FVS includes the record when it backdates stand attributes during the calibration of the model. In the latter case (older dead), FVS ignores the record during calibration.

Table 2. – FVS Tree History Codes

Code	Description
1-5	live
6-7	recent dead
8-9	older dead

Species Codes

The Southeast variant includes the following tree species or species groups.

Table 3. – Southeast Variant Tree Species Codes

Code	Alpha Code	FIA Code	Common Name	Scientific Name
1	RC	068	eastern redcedar	Juniperus virginiana
2	JU	060	juniper sp.	Juniperus sp.
3	SP	110	shortleaf pine	Pinus echinata
4	SA	111	slash pine	Pinus elliottii
5	SR	115	spruce pine	Pinus glabra
6	LL	121	longleaf pine	Pinus palustris
7	PZ	122	ponderosa pine	Pinus ponderosa
8	PP	126	pitch pine	Pinus rigida
9	PD	128	pond pine	Pinus serotina
10	WP	129	eastern white pine	Pinus strobus
11	LP	131	loblolly pine	Pinus taeda
12	VP	132	Virginia pine	Pinus virginiana
13	BY	221	baldcypress	Taxodium distichum
14	PC	222	pondcypress	Taxodium distichum var. nutans
15	EH	261	eastern hemlock	Tsuga canadensis
16	MP	935	American mountain-ash	Sorbus americana
17	CM	310	chalk maple	Acer leucoderme
18	BE	313	boxelder	Acer negundo
19	RM	316	red maple	Acer rubrum
20	SV	317	silver maple	Acer saccharinum
21	SM	318	sugar maple	Acer saccharum
22	OB	331	Ohio buckeye	Aesculus glabra
23	BB	370	birch sp.	Betula sp.
24	YB	371	yellow birch	Betula alleghaniensis
25	SB	372	black/sweet birch	Betula lenta
26	RB	373	river birch	Betula nigra
27	AH	391	American hornbeam	Carpinus caroliniana
28	HI	400	hickory sp.	Carya sp.
29	WH	401	water hickory	Carya aquatica
30	BH	402	bitternut hickory	Carya cordiformis
31	PH	403	pignut hickory	Carya glabra
32	PE	404	pecan	Carya illinoensis
33	SL	405	shellbark hickory	Carya laciniosa
34	SH	407	shagbark hickory	Carya ovata
35	BI	408	black hickory	Carya texana
36	MH	409	mockernut hickory	Carya tomentosa
37	CA	450	catalpa sp.	Catalpa sp.
38	HB	462	hackberry	Celtis occidentalis
39	SG	461	sugarberry	Celtis laevigata
40	RD	471	eastern redbud	Cercis canadensis
41	DW	490	dogwood sp.	Cornus sp.
42	HT	500	hawthorn sp.	Crataegus sp.
43	PS	521	common persimmon	Diospyros virginiana
44	AB	531	American beech	Fagus grandifolia
45	AS	540	ash sp.	Fraxinus sp.
46	WA	541	white ash	Fraxinus americana
47	BA	543	black ash	Fraxinus nigra
48	GA	544	green ash	Fraxinus pennsylvanica
49	PA	545	pumpkin ash	Fraxinus profunda

Code	Alpha Code	FIA Code	Common Name	Scientific Name
50	BS	546	blue ash	Fraxinus quadrangulata
51	HL	552	honeylocust	Gleditsia triacanthos
52	LB	555	loblolly-bay	Gordonia lasianthus
53	KC	571	Kentucky coffeetree	Gymnocladus dioicus
54	HY	591	American holly	Ilex opaca
55	BN	601	butternut	Juglans cinerea
56	WN	602	black walnut	Juglans nigra
57	SU	611	sweetgum	Liquidambar styraciflua
58	YP	621	yellow-poplar	Liriodendron tulipifera
59	OR	641	Osage-orange	Maclura pomifera
60	CT	651	cucumbertree	Magnolia acuminata
61	MG	652	southern magnolia	Magnolia grandiflora
62	MV	653	sweetbay	Magnolia virginiana
63	MB	680	mulberry sp.	Morus sp.
64	WM	681	white mulberry	Morus alba
65	RY	682	red mulberry	Morus rubra
66	WT	691	water tupelo	Nyssa aquatica
67	OG	692	ogeechee tupelo	Nyssa ogeche
68	BG	693	black tupelo	Nyssa sylvatica
69	TS	694	swamp tupelo, swamp blackgum	Nyssa sylvatica var. biflora
70	HH	701	eastern hophornbeam, ironwood	Ostrya virginiana
71	SD	711	sourwood	Oxydendrum arboreum
72	RA	721	redbay	Persea borbonia
73	SY	731	sycamore	Platanus occidentalis
74	CW	740	cottonwood and poplar sp.	Populus sp.
75	BP	741	balsam poplar	Populus balsamifera
76	EC	742	eastern cottonwood	Populus deltoides
77	BT	743	bigtooth aspen	Populus grandidentata
78	QA	746	quaking aspen	Populus tremuloides
79	BC	762	black cherry	Prunus serotina
80	WO	802	white oak	Quercus alba
81	SW	804	swamp white oak	Quercus bicolor
82	SO	806	scarlet oak	Quercus coccinea
83	QN	840	bluejack oak	Quercus incana
84	NP	809	northern pin oak	Quercus ellipsoidalis
85	SK	812	southern red oak	Quercus falcata var. falcata
86	CB	813	cherrybark oak, swamp red oak	Quercus falcata var. pagodaefolia
87	QI	817	shingle oak	Quercus imbricaria
88	TO	819	turkey oak	Quercus laevis
89	LK	820	laurel oak	Quercus laurifolia
90	OV	822	overcup oak	Quercus lyrata
91	BR	823	bur oak	Quercus macrocarpa
92	BJ	824	blackjack oak	Quercus marilandica
93	SN	825	swamp chestnut oak	Quercus michauxii
94	CK	826	chinkapin oak	Quercus muehlenbergii
95	WK	827	water oak	Quercus nigra
96	NO	828	Nuttall oak	Quercus nuttallii
97	PN	830	pin oak	Quercus palustris
98	WL	831	willow oak	Quercus phellos
99	CO	832	chestnut oak	Quercus prinus
100	RO	833	northern red oak	Quercus rubra

Alpha Code	FIA Code	Code	Common Name	Scientific Name
101	QS	834	Shumard oak	Quercus shumardii
102	PO	835	post oak	Quercus stellata
103	DO	836	Delta post oak	Quercus stellata var. mississippiensis
104	BO	837	black oak	Quercus velutina
105	LO	838	live oak	Quercus virginiana
106	DP	846	sand, dwarf post oak	Quercus stellata var. margaretta
107	BK	901	black locust	Robinia psuedoacacia
108	WI	920	willow sp.	Salix sp.
109	BL	922	black willow	Salix nigra
110	SS	931	sassafras	Sassafras albidum
111	BW	951	American basswood	Tilia americana
112	EL	970	elm sp.	Ulmus sp.
113	WE	971	winged elm	Ulmus alata
114	AE	972	American elm	Ulmus americana
115	SI	974	Siberian elm	Ulmus pumila
116	RL	975	slippery elm	Ulmus rubra
117	RE	977	rock elm	Ulmus thomasii
118	NC	999	noncommercial hardwood sp.	

Diameter and Height Codes

Information in the tree data file for ***diameter, diameter increment, height-to-topkill,*** and ***height increment*** is coded the same for all FVS variants. Table 1 describes the format for these fields.

Crown Ratio

There are nine codes FVS recognizes to represent crown ratio. This code is the same for all FVS variants.

Table 4. – FVS Crown Ratio Codes

Code	Crown Percent	Code	Crown Percent
1	1-10	6	51-60
2	11-20	7	61-70
3	21-30	8	71-80
4	31-40	9	81-100
5	41-50		

Tree Damage and Severity Codes

The Southeast variant recognizes the following damage codes. They are important for volume computations and for tagging tree records for user-defined purposes. Up to three pairs of codes may be entered per record.

Table 5. – Tree Damage and Severity Codes for the Southeast Variant

Damage		Severity	
Agent	Code	Code	Description
Individual Tree Defect %	25	0-99	Percentage of pulpwood and sawtimber affected.

Damage		Severity	
Agent	Code	Code	Description
	26	0-99	Percentage of pulpwood affected.
	27	0-99	Percentage of sawtimber affected.
Special tree status	55	0-99	User defined.
Physical defect:			
Unspecified		95	0 < 5% volume loss.
Broken/missing top		96	1 5-15% volume loss.
Dead top		97	2 16-25% volume loss.
Fork, crook, sweep		98	3 26-35% volume loss.
Checks, bole cracks		99	4 36-45% volume loss.
			5 46-55% volume loss.
			6 56-65% volume loss.
			7 66-75% volume loss.
			8 76-85% volume loss.
			9 86-100% volume loss.

Tree Value Class

Tree value class is a code that denotes a tree's relative value in the stand. Keywords can reference this code to mark a tree for retention or harvest. This code is the same for all FVS variants, but may have different local interpretations.

Table 6. – FVS Tree Value Class Codes

Code	Tree Value Class
1	desirable
2	acceptable
3	cull

Cut or Leave Prescription Code

The prescription code is an optional label for each tree that can be used to retain or remove the tree in a simulation. This value has no intrinsic value to FVS, but can be used as a user-specified code to mark a tree for removal using the ThinPRSC keyword. A code of '0' through '9' is an acceptable entry in this field.

Plot Information Fields

The coding of the remaining tree data fields is the same for the Southeast Variant as it is with other FVS variants. The Southeast Variant may use ***plot slope, aspect,*** and ***site preparation***. The Southeast Variant does not use ***habitat type*** and ***topographic position***.

Suppose Stand List File

The ***Stand List File*** (.slf file extension; also called the SLF file) contains plot information for each stand. All stands comprising a geographic location listed in the Suppose locations file are contained in separate Stand List Files.

The records in this file are coded free form; specific column location is not important. There are four Record Types: A, B, C, and D. Record Types A and B are required entries. Record Types C and D are optional.

Record Type A

The A Record includes information about the stand, a reference to the tree data file, whether the plot includes specific point data, and the variants that Suppose can use with the data.

Field 1: Record Type: always code an A.
Field 2: Stand Identification code; limited to 26 characters.
Field 3: FVS-ready tree data file name.
Field 4: Sample point site data flag. "**WithPointData**" indicates the sample points within sample plots contain independent site data in the tree data. "**NoPointData**" indicates otherwise. Sample point site data are point measures of slope, aspect, habitat type, topographic position, and site preparation.
Field 5: FVS Variant(s) to which the plot and tree data apply. This field is a list of 2-character variant identifiers (always in lower case), such as "se" for the Southeast Variant. More than one variant can be included in this field, but the first variant listed is the variant Suppose will use as the default for the stand data. The list is ended with an @ symbol.

Record Type B

Suppose uses the specific information about the stand from the B Record to populate the fields of various FVS keywords that tell FVS about the stand and its inventory. The data included in the B Record's fields is similar for all FVS variants, but there are codes specific to the Southeast Variant. Descriptions of specific Southeast Variant codes follow.

Field 1: Record Type: always code a B.
Field 2: Stand Identification code. Limited to 26 characters and must be identical to the code used in record type A.
Field 3: Inventory year. For permanent plots, designate last growing season.
Field 4: Latitude in degrees (not used by the Southeast Variant).
Field 5: Longitude in degrees (not used by the Southeast Variant).
Field 6: Location code: the Forest Service Region, Forest, and District Code for the Southeast Variant, 5-digits (Table 7).
Field 7: Habitat type or Plant Association (not used by the Southeast Variant).
Field 8: Stand Year of Origin.
Field 9: Aspect in degrees (not used by the Southeast Variant, except for Ponderosa pine).
Field 10: Slope percent (not used by the Southeast Variant, except for Ponderosa pine).
Field 11: Elevation in 100's of feet (not used by the Southeast Variant, except for Ponderosa pine).
Field 12: Positive value = Basal area factor / Negative value = Inverse of large-tree fixed area plot in acres.
Field 13: Inverse of small-tree fixed area plot in acres.
Field 14: Breakpoint DBH in inches between large-tree and small-tree sample design.
Field 15: Number of plots (not points) represented associated tree file.
Field 16: Number of non-stockable plots.
Field 17: Stand sampling weight (or size) used to compute weighted average yield tables and other weighted averages among some set of stands..
Field 18: Stockable percent.
Field 19: Diameter growth translation code as defined for FVS.
Field 20: Diameter growth measurement period.
Field 21: Height growth translation code as defined for FVS.
Field 22: Height growth measurement period.
Field 23: Mortality measurement period.
Field 24: Maximum basal area.

Field 25: Maximum stand density index.

Field 26: Site Index Species: Important with the Southeast Variant. The variant's default site index species is loblolly.

Field 27: Site Index.

Field 28: Model Type (There is only one model type in the Southeast Variant.).

Field 29: Physiographic Region Code (see discussion below and Tables 8 and 9).

Field 30: Forest Type Code (see discussion below and Table 10).

Location Codes

Location codes (Field 6) relate to the Region, National Forest, and Ranger District where the stand is located. The Southeast Variant uses this information to select the appropriate volume equations for the stand. The code is in the format RFFDD, where R is the region number, FF is the forest number, and DD is the ranger district number. If a location code is not entered or an incorrect code is entered, the default code is 80308, the Oconee National Forest, Oconee District. Although the Southeast Variant is most appropriately used within Alabama, Georgia, or South Carolina, the variant has been programmed to recognize any National Forest and District in the Southern Region.

Table 7. – Location Codes for the Southeast Variant

Proclaimed National Forest	**District**	**Location Code**
National Forests in Alabama	Bankhead	80101
	Conecuh	80103
	Oakmulgee	80104
	Shoal Creek	80105
	Talledega	80106
	Tuskegee	80107
Daniel Boone	Morehead	80211
	Stanton	80212
	Berea	80213
	London	80214
	Somerset	80215
	Stearns	80216
	Redbird	80217
Chattahoochee-Oconee	Armuchee	80301
	Toccoa	80302
	Brasstown	80304
	Tallulah	80305
	Chattooga	80306
	Cohutta	80307
	Oconee	80308
Cherokee	Hiwassee	80401
	Nolichucky	80402
	Ocoee	80403
	Tellico	80404
	Unaka	80405
	Watuga	80406
National Forests in Florida	Apalachicola	80501
	Lake George	80502
	Osceola	80504
	Seminole	80505
	Wakulla	80506
Kisatchie	Catahoula	80601
	Evangeline/Vernon	80602
	Kisatchie	80603
	Winn	80604

Proclaimed National Forest **District** **Location Code**

Kisatchie	Caney	80605
National Forests in Mississippi	Bienville	80701
	Desoto	80702
	Homochitto	80704
	Chickasawhay	80705
	Delta	80706
	Holly Springs	80707
	Tombigbee	80717
George Washington/Jefferson NFs	Deerfield	80801
	Dry River	80802
	James River	80803
	Lee	80804
	Pedlar	80805
	Warm Springs	80806
	Blacksburg	80811
	Clinch	80812
	Glenwood	80813
	Mt. Rogers	80814
	New Castle	80815
	Wythe	80816
Quachita	Choctaw	80901
	Caddo	80902
	Cold Springs	80903
	Fourche	80904
	Jessieville	80905
	Kiamichi	80906
	Mena	80907
	Oden	80908
	Poteau	80909
	Womble	80910
	Winona	80911
	Tiak	80912
Ozark & St. Francis NFs	Sylamore	81001
	Buffalo	81002
	Bayou	81003
	Pleasant Hill	81004
	Boston Mountain	81005
	Magazine	81006
	St. Francis	81007
National Forests in North Carolina	Cheoah	81102
	Croatan	81103
	Appalachian	81104
	Grandfather	81105
	Highlands	81106
	Pisgah	81107
	Tusquitee	81109
	Uwharrie	81110
	Wayah	81111
Francis Marion & Sumter NFs	Enoree/Tyger	81201
	Andrew Pickens	81202
	Long cane	81203
	Wambaw/Witherbee	81205
National Forests in Texas	Angelina	81301
	Davy Crockett	81303
	Sam Houston	81304
	Sabine	81307
	Caddo/LBJ	81308

Physiographic Region

The Southeast Variant is unique in its need for the physiographic region variable. The model uses this information in growth functions. See Appendix 1 for physiographic regions by county for Alabama, Georgia, and South Carolina.

Table 8. – Physiographic Region Codes for the Southeast Variant

Physiographic Region	**Alpha-Code**	**Numeric-Code**
Flatland Coastal Plains	FCP	1
Middle Costal Plains	MCP	2
Hilly Coastal Plains	HCP	3
Piedmont	PIE	4
Ridge and Valley	VAL	5
Blue Ridge Mountains	BLU	6
Cumberland Plateau	CMP	7
Limestone Plateau	LPL	8

In the absence of a physiographic region entry, default physiographic regions correspond to the forest and district numbers of the Location Code. Avoid using the default unless this is the true physiographic region for the stand(s). Model projections will change with different physiographic regions.

Table 9. – Default Physiographic Region by Location Code

Proclaimed National Forest	**District**	**Location Code**	**Physiographic Region**
National Forests in Alabama	Bankhead	80101	CMP
	Conecuh	80103	FCP
	Oakmulgee	80104	MCP
	Shoal Creek	80105	VAL
	Talledega	80106	VAL
	Tuskegee	80107	MCP
Daniel Boone	Morehead	80211	CMP
	Stanton	80212	CMP
	Berea	80213	CMP
	London	80214	CMP
	Somerset	80215	CMP
	Stearns	80216	CMP
	Redbird	80217	CMP
Chattahoochee-Oconee	Armuchee	80301	VAL
	Toccoa	80302	BLU
	Brasstown	80304	BLU
	Tallulah	80305	BLU
	Chattooga	80306	VAL
	Cohutta	80307	BLU
	Oconee	80308	PIE
Cherokee	Hiwassee	80401	BLU
	Nolichucky	80402	BLU
	Ocoee	80403	BLU
	Tellico	80404	BLU
	Unaka	80405	BLU
	Watuga	80406	BLU

Proclaimed National Forest	District	Location Code	Physiographic Region
National Forests in Florida	Apalachicola	80501	FCP
	Lake George	80502	FCP
	Osceola	80504	FCP
	Seminole	80505	FCP
	Wakulla	80506	FCP
Kisatchie	Catahoula	80601	FCP
	Evangeline/Vernon	80602	FCP
	Kisatchie	80603	FCP
	Winn	80604	FCP
	Caney	80605	MCP
National Forests in Mississippi	Bienville	80701	MCP
	Desoto	80702	FCP
	Homochitto	80704	FCP
	Chickasawhay	80705	FCP
	Delta	80706	MCP
	Holly Springs	80707	MCP
	Tombigbee	80717	MCP
George Washington/Jefferson NFs	Deerfield	80801	VAL
	Dry River	80802	VAL
	James River	80803	VAL
	Lee	80804	VAL
	Pedlar	80805	BLU
	Warm Springs	80806	VAL
	Blacksburg	80811	VAL
	Clinch	80812	CMP
	Glenwood	80813	BLU
	Mt. Rogers	80814	BLU
	New Castle	80815	VAL
	Wythe	80816	VAL
Quachita	Choctaw	80901	CMP
	Caddo	80902	CMP
	Cold Springs	80903	CMP
	Fourche	80904	CMP
	Jessieville	80905	CMP
	Kiamichi	80906	CMP
	Mena	80907	CMP
	Oden	80908	CMP
	Poteau	80909	CMP
	Womble	80910	CMP
	Winona	80911	CMP
	Tiak	80912	MCP
Ozark & St. Francis NFs	Sylamore	81001	LPL
	Buffalo	81002	LPL
	Bayou	81003	LPL
	Pleasant Hill	81004	LPL
	Boston Mountain	81005	LPL
	Magazine	81006	VAL
	St. Francis	81007	MCP
National Forests in North Carolina	Cheoah	81102	BLU
	Croatan	81103	FCP
	Appalachian	81104	BLU
	Grandfather	81105	BLU
	Highlands	81106	BLU
	Pisgah	81107	BLU
	Tusquitee	81109	BLU
	Uwharrie	81110	PIE

Proclaimed National Forest	District	Location Code	Physiographic Region
National Forests in North Carolina	Wayah	81111	BLU
Francis Marion & Sumter NFs	Enoree/Tyger	81201	PIE
	Andrew Pickens	81202	BLU
	Long cane	81203	PIE
	Wambaw/Witherbee	81205	FCP
National Forests in Texas	Angelina	81301	FCP
	Davy Crockett	81303	MCP
	Sam Houston	81304	MCP
	Sabine	81307	FCP
	Caddo/LBJ	81308	MCP

Forest Type

The forest type code is a variable in the Southeast Variant's growth algorithms. These forest types are specific forest types or forest type groups from the Eastwide Forest Inventory Data Base. The plantation forest types are not included in the Eastwide Data Base, but were created specifically for the Southeast Variant to differentiate between planted and natural stands. See Appendix 2 for a complete description of forest types.

Table 10. – Forest Types of the Southeast Variant

Code	Forest Type
4	white pine
5	loblolly pine plantation
6	shortleaf pine plantation
7	longleaf pine plantation
21	longleaf pine
22	slash pine
31	loblolly pine
32	shortleaf pine
33	Virginia pine
35	eastern red-cedar
36	pond pine
38	pitch pine
40	oak-pine
50	oak-hickory
52	chestnut oak
57	Southern scrub oak
60	oak-gum-cypress
70	elm-ash-cottonwood

Record Types C and D

There are no fields in either of these records that have specific Southeast Variant Codes. Record Type C includes information about stand group membership and Record Type D includes information about keyword component files ("addfiles") associated with the stand. This document will not attempt to describe these record types.

Suppose Locations File

The Suppose Locations file, "suppose.loc", provides a reference to the stand list file(s) for a Suppose project. There are no fields in this file that are specific to the Southeast Variant. This document will not describe this file any further.

The Large-tree Model

Large-tree Diameter Growth Model

The large tree (greater than or equal to 5.0 inches DBH) diameter increment model is a function of the product of a maximum diameter and a modifier. The Southeast variant uses 16 equation forms for the modifier function. The equation that the model uses is dependent upon the species, forest type, physiographic region, and whether the tree is a pine, oak, or non-oak species.

Pine:

$$DELD = (A_1 \times SI) / \left(1.0 + \exp\left(-1.0 \times (A_2 \times DBH + A_3 \times TBAL)\right)\right)$$
$$DELD = \left((A_1 \times SI) + (A_2 \times TAB)\right) / \left(\exp(-1.0 \times TBAL \times A_3)\right)$$
$$DELD = (A_1 \times SI) / \left(1.0 + \exp(-1.0 \times TAB + A_2)\right)$$
$$DELD = (A_1 \times SI) / \left(1.0 + \exp(-1.0 \times A_2 \times TAB + A_3 \times TBAL)\right)$$
$$DELD = A_1 + A_2 \times TPA$$

Oak:

$$DELD = \left((A_1 \times SI) + (A_2 \times TAB)\right) / \left(\exp(-1.0 \times A_3 \times TBAL)\right)$$
$$DELD = (A_1 \times SI) / \left(1.0 + \exp(-1.0 \times A_2 \times TBAL)\right)$$
$$DELD = (A_1 \times SI) / \left(1.0 + \exp(-1.0 \times A_2 \times TBAL + A_3 \times DBH)\right)$$
$$DELD = (A_1 \times SI) / \left(1.0 + \exp(-1.0 \times A_2 \times TAB + A_3 \times DBH)\right)$$
$$DELD = A_1 + A_2 \times DBH + A_3 \times TPA + A_4 \times TBAL + A_5 \times CR + A_6 \times DBH \times TPA / SUMDT$$
$$DELD = A_1 + A_2 \times DBH + A_3 \times TAB + A_4 \times TBAL + A_5 \times CR + A_6 \times DBH \times TPA / SUMDT$$

Non-oak:

$$DELD = (A_1 \times SI + A_2 \times TAB) / \left(1.0 + \exp(-1.0 \times A_3 \times TBAL)\right)$$
$$DELD = (A_1 \times SI) / \left(1.0 + \exp(-1.0 \times A_2 \times TBAL)\right)$$
$$DELD = A_1 + A_2 \times SI + A_3 \times SI \times DBH + A_4 \times TBAL + A_5 \times TPA + A_6 \times DBH$$
$$DELD = A_1 + A_2 \times CR + A_3 \times TAB + A_4 \times SI \times DBH \times TPA / SUMDT + A_5 \times DBH$$
$$DELD = A_1 + A_2 \times TBAL + A_3 \times SI + A_4 \times TPA$$

where:

DELD = maximum diameter increment modifier
DBH = current tree diameter at breast height
SI = species site index
TPA = trees per acre
CR = crown ratio
SUMDT = sum of tree's diameter times trees per acre
TAB = total trees per acre in trees with diameters larger than or equal to subject tree
TBAL = total basal area per acre in trees with diameters larger than or equal to subject tree
A_1 *to* A_6 = coefficients related to species, forest type, physiographic region, and whether the tree is a pine, oak, or non-oak

The model then calculates a maximum diameter based on whether the tree is pine, oak, or non-oak species. It uses two equations to calculate maximum diameter.

$$DMAX = B_1 \times \left(1.0 - \exp(B_2 / DBH)\right)$$
$$DMAX = B_1 \times \left(1.0 - \exp(B_2 \times DBH)\right)$$

where:

$DMAX$ = maximum diameter
B_1 and B_2 = coefficients related to species, forest type, physiographic region, and whether the tree is a pine, oak, or non-oak.
DBH = current tree diameter at breast height

The model then calculates diameter growth:

$$DIAMGR = 10.0 \times DELD \times DMAX$$ where: DIAMGR = diameter growth

Crown Ratio Equations

The model estimated the initial crown ratios for trees that lack a measured crown ratio and the change in crown ratio by using one of three equations developed by Meldahl and Bolton (1989). Species group (pine, oak, or non-oak) determines the equation that the model uses. Species, physiographic region, forest type, and species group (pine, oak or non-oak) are the basis of the equation coefficients. The change in crown ratio from one cycle to the next is limited to 10 percent

Pine:

$$CR = 100.0 \times \left(A_1 + A_2 \times DBH \times TPA / SUMDT + A_3 \times TBAL + A_4 \times TPA + A_5 \times SI \right)$$

Oak:

$$CR = 100.0 \times \left(A_1 + A_2 \times DBH + A_3 \times TBAL + A_4 \times TPA + A_5 \times SI \right)$$

Non-oak:

$$CR = 100.0 \times \left(A_1 + A_2 \times DBH + A_3 \times TBAL + A_4 \times TPA + A_5 \times SI + 0.0001948 \times TAB \right)$$

where:

CR = crown ratio, in percent
DBH = current tree diameter at breast height
TPA = trees per acre
$SUMDT$ = sum of tree's diameter times trees per acre representation
TAB = total trees per acre in trees with diameters larger than or equal to subject tree
$TBAL$ = total basal area per acre in trees with diameters larger than or equal to subject tree
SI = stand site index
A_1 *to* A_5 = coefficients related to species, forest type, physiographic region, and whether the tree is a pine, oak, or non-oak

Volume Calculations

The model determines total and merchantable cubic foot and board foot volume for all trees that meet the sawlog criterion. It determines total cubic foot volume for all pulpwood trees. Default merchantability limits by product class and species group are displayed in Table 11 below.

Table 11. – Default Merchantability Standards for the Southeast Variant.

	Min. DBH (inches)	Min. Top DOB (inches)
Sawtimber		
Softwood	10.0	7.0
Hardwood	12.0	9.0
Pulpwood		
Softwood	4.0	4.0
Hardwood	4.0	4.0

The default stump height is 0.5 feet for pulpwood-size trees and 1.0 foot for sawlog-size trees. The default form class is 80. The user can change these defaults with the VOLUME and BFVOLUME keywords.

Cubic-foot volume equations come from Clark et. al (1991). FVS performs the volume calculations based upon conventions used in the National Cruise Program (NATCRS) for the Southern Region. The volume equations used in a particular location are associated with a National Forest and Ranger District. The previous Table 9 displays the related National Forests, Ranger Districts, and Physiographic Regions (Location Codes).

The model calculates total height to a default or user-defined top-height before it calculates volume. This equation is from Clark et. al. (1991):

$$
\begin{aligned}
HT = {} & I_s \times H\left\{1-\left[\left(d^2/D^2-1\right)/\left[\left(c+e/D^3\right)/(1-G)\right]+G\right]^{1/r}\right\} \\
& + I_b \times H\left\{1-\left[X-\left(D^2-d^2\right)/Z\right]^{1/p}\right\} \\
& + I_t \times \left\{17.3+(H-17.3)\left[-Q_b-\left(Q_b^2-4Q_aQ_c\right)^{0.5}/\left(2Q_a\right)\right]\right\}
\end{aligned}
$$

where:

HT = height to specified top diameter, d
H = total tree height
I_s = 1 if $d^2 > D^2$, otherwise 0
I_b = 1 if $D^2 > d^2 \geq F^2$, otherwise 0
I_t = 1 if $F^2 > d^2$
d = specified top height diameter, outside bark
D = diameter at breast height
F = diameter at 17.3 feet (estimated)
$G = (1-4.5/H)^r$
$X = (1-4.5/H)^p$
$Y = (1-17.3/H)^p$
$Z = (D^2-F^2)/(X-Y)$
$T = D^2$-ZX
$Q_a = b+I_m(1-b)/a^2$
$Q_b = -2b-I_m*2(1-b)/a$
$Q_c = b+(1-b)*I_m-d^2/F^2$
I_m = 1 if $D^2 > b(a-1)^2 * F^2$, *otherwise 0*
r, c, e = regression coefficients for stem section below 4.5 feet
p = regression coefficient for stem section between 4.5 and 17.3 feet
a, b = regression coefficients for stem section above 17.3 feet

To calculate cubic-foot volumes, a profile model creates a model that will calculate the cubic-foot volume of the tree bole between any two points (Clark et. al. 1991). The integrated profile models are of the form:

$$
\begin{aligned}
VOL = 0.005454\Big[& I_1 D^2 \Big\{(1-GW)(U_1+L_1) + W\Big(\big(1-L_1/H\big)^r (H-L_1) - \big(1-U_1/H\big)^r (H-U_1)\Big)\Big/(r+1)\Big\} \\
& + I_2 I_3 \Big\{T(U_2-L_2) + Z\Big(\big(1-L_2/H\big)^p (H-L_2) - \big(1-U_2/H\big)^P (H-U_2)\Big)\Big/(p+1)\Big\} \\
& + I_4 F^2 \Big\{b(U_3-L_3) - b\Big((U_3-17.3)^2 - (L_3-17.3)^2\Big)\Big/(H-17.3) + (b/3)\Big((U_3-17.3)^3 - (L_3-17.3)^3\Big)\Big/(H-17.3)^2 \\
& + I_5 (1/3)\big((1-b)/a^2\big)\big(a(H-17.3)-(L_3-17.3)\big)^3 \Big/ (H-17.3)^2 \\
& - I_6 (1/3)\big((1-b)/a^2\big)\big(a(H-17.3)-(U_3-17.3)\big)^3 \Big/ (H-17.3)^2 \Big\}\Big]
\end{aligned}
$$

where:

VOL = stem volume between any two heights, L and U, in cubic feet
L = lower height of interest in feet (default is 0.5 feet for pulpwood, 1.0 feet for sawlogs)
U = upper height of interest in feet, determined by previous equation
D = diameter at breast height
F = diameter at 17.3 feet (estimated)
$G = (1\text{-}4.5/H)^r$
H = total tree height in feet
$W = (c+e/D^2)/(1\text{-}G)$
$T = D^2\text{-}ZX$
$Z = (D^2\text{-}F^2)/(X\text{-}Y)$
L_1 = maximum of L and 0
U_1 = minimum of U and 4.5
L_2 = maximum of L and 4.5
U_2 = minimum of U and 17.3
L_3 = maximum of L and 17.3
U_3 = minimum of U and H
I_1 = 1 if $L < 4.5$ otherwise 0
I_2 = 1 if $L < 17.3$ otherwise 0
I_3 = 1 if $U > 4.5$ otherwise 0
I_4 = 1 if $U > 17.3$ otherwise 0
I_5 = 1 if $(L_3\text{-}17.3) < a(H\text{-}17.3)$ otherwise 0
I_6 = 1 if $(U_3\text{-}17.3) < a(H\text{-}17.3)$ otherwise 0
r = regression coefficient for stem section below 4.5 feet
p = regression coefficient for stem section between 4.5 and 17.3 feet
a, b = regression coefficients for stem section above 17.3 feet

Mortality

The mortality model determines a mortality rate for each tree based on a stand's stand density index (SDI) in relation to the maximum SDI. This mortality rate will be non-zero when the stand SDI is above 55 percent of maximum SDI. Stand density will continue to build and peak at 85 percent of maximum SDI. These percentages can be changed using fields 5 and 6 of the SDIMAX keyword. Users can also set maximum SDI values for any, or all, species with this keyword. SDI is computed with the following equation:

$$SDI = N(D/10)^{1.605}$$

where: *SDI* = stand density index
N = number of tree per acre in the stand
D = quadratic mean diameter in the stand

The BAMAX keyword can be used to enter a maximum basal area for a stand. If one is not entered, then a default value is assigned (Table 12). The basal area maximum is converted into a maximum SDI within the model for use in mortality. This maximum SDI value is assigned to all species for which the user did not set a maximum using the SDIMAX keyword.

Table 12. – Default Stand Density Indices for the Southeast Variant

Species	Maximum SDI
RC,JU,SP,SA,SR,LL,PZ,PP,PD,WP,LP,VP,EH	250
BY,PC,BE,HB,SG,RD,DW,HT,PS,HL,LB,KC,HY, BN,WN,SU,YP,OR,CT,MG,MV,MB,WM,RY,WT, OG,BG,TS,HH,SD,RA,SY,SK,RO,BK,WI,BL,SS	275
MP,CM,RM,SV,SM,OB,BB,YB,SB,RB,AH,HI,WH, BH,PH,PE,SL,SH,BI,MH,CA,AB,AS,WA,BA,GA, PA,BS,CW,BP,EC,BT,QA,BC,WO,SW,SO,QN,NP, CB,QI,TO,LK,OV,BR,BJ,SN,CK,WK,NO,PN,WL, CO,QS,PO,DO,BO,LO,DP,BW,EL,WE,AE,SI,RL, RE,NC	300

The model also computes a mortality rate for each tree using equations from the Southeast TWIGS model. The larger of the two computed mortality rates (SDI based rate and SE TWIGS rate) is the one that is applied to the tree record.

The Southeast TWIGS model uses eight equations to predict mortality in trees with diameters greater than or equal to 5.0 inches. The equations that FVS uses depend upon physiographic region, species, species group (pine, oak, or non-oak), forest type, and DBH.

Pine:

$$TMORT = A_1 + A_2 \times CR^3 + A_3 \times TAB + A_4 \times TBAL + A_5 \times DGR + A_6 \times DBH; \quad when \quad DBH \geq 5.0$$

$$TMORT = A_1 + A_2 \times CR^3 + A_3 \times DBH + A_4 \times TBAL + A_5 \times DGR + A_6 \times DBH; \quad when \quad DBH \geq 5.0$$

$$TMORT = A_1 + A_2 \times TPA + A_3 \times SI + A_4 \times DBH \times TPA / SUMDT + A_5 \times DGR + A_6 \times CR^3; \quad when \quad DBH \leq 5.0$$

Oak:

$$TMORT = A_1 + A_2 \times DGR + A_3 \times DBH + A_4 \times CR \times SI + A_5 \times DBH \times TPA / SUMDT; \quad when \quad DBH \geq 5.0$$

$$TMORT = A_1 + A_2 / DGR + A_3 / DBH + A_4 \times CR \times SI + A_5 \times TPA; \quad when \quad DBH \geq 5.0$$

$$TMORT = A_1 + A_2 \times DBH \times TPA / SUMDT + A_3 \times DGR + A_4 \times CR / SI + A_5 \times DBH; \quad when \quad DBH \leq 5.0$$

Non-oak:

$$TMORT = A_1 + A_2 \times CR^3 + A_3 \times DBH + A_4 \times DGR + A_5 \times TPA + A_6 \times DBH \times TPA / SUMDT; \quad when \quad DBH \geq 5.0$$

$$TMORT = A_1 + A_2 / DBH + A_3 \times DBH \times TPA / SUMDT + A_4 \times CR / SI + A_5 \times TPA + A_6 \times DGR; \quad when \quad DBH \leq 5.0$$

where:

TMORT = percent survival (0-100) on a 10-year basis
A_1 *to* A_6 = coefficients related to species, forest type, physiographic region, and whether the tree is a pine, oak, or non-oak
CR = crown ratio
TAB = total trees per acre in trees with diameters larger than or equal to subject tree
TBAL = total basal area per acre in trees with diameters larger than or equal to subject tree
DGR = diameter growth
DBH = current tree diameter at breast height
TPA = trees per acre
SUMDT = sum of tree's diameter times trees per acre representation
SI = species site index

Height Growth and Height Dubbing

To predict height growth for trees with diameters greater than or equal to 5.0 inches DBH, the model calculates height growth by determining the height of the tree at present. It then subtracts that height from the predicted tree height at the end of the cycle. The variant applies the same height growth equation form to all species, except eastern hemlock or if the species is ponderosa pine and the forest type is 21 (shortleaf). The following equation applies to all but the latter species and forest type.

$$HT = B_1 + B_2 \times DBH + B_3 \times SI$$

where:

HT = tree height
B_1 *to* B_3 = specific species group height coefficients (refer to the following tables regarding species height groups and related height coefficients)
DBH = tree diameter at breast height
SI = stand site index

There are 32 species height groups for the Southeast variant. There are height coefficients corresponding to each height group, B_1 *to* B_3. in the preceding equation. Tables 13 and 14 displays the height group and related coefficients for each Southeast TWIGS species.

Table 13. – Height Groups for the Southeast Variant

Species Code	Height Group	Species Code	Height Group	Species Code	Height Group	Species Code	Height Group
RC	1	PH	10	MG	31	BR	32
J	1	PE	10	MV	15	BJ	32
SP	2	SL	10	MB	32	SN	32
SA	3	SH	10	WM	32	CK	32
SR	4	BI	10	RY	32	WK	23
LL	5	MH	10	WT	16	NO	32
PZ	5	CA	31	OG	31	PN	32
PP	2	HB	31	BG	17	WL	24
PD	3	SG	31	TS	18	CO	25
WP	7	RD	31	HH	32	RO	26
LP	6	DW	32	SD	31	QS	32
VP	7	HT	32	RA	31	PO	27
BY	8	PS	32	SY	31	DO	32
PC	32	AB	11	CW	31	BO	28
EH	1	AS	12	BP	31	LO	32
MP	32	WA	12	EC	31	DP	32
CM	32	BA	12	BT	31	BK	32
BE	31	GA	12	QA	31	WI	31
RM	9	PA	12	BC	31	BL	31
SV	31	BS	12	WO	19	SS	31
SM	32	HL	32	SW	32	BW	31
OB	32	LB	31	SO	20	EL	30
BB	32	KC	31	QN	32	WE	32
YB	32	HY	32	NP	32	AE	32
SB	10	BN	31	SK	21	SI	32
RB	32	WN	32	CB	32	RL	32
AH	32	SU	13	QI	32	RE	32
HI	10	YP	14	TO	32	NC	32
WH	10	OR	31	LK	22		
BH	10	CT	31	OV	32		

Table 14. – Species Height Group Coefficients for the Southeast Variant

Height Group	Height Coefficients			Height Group	Height Coefficients		
	B_1	B_2	B_3		B_1	B_2	B_3
1	23.02	1.86	0.035	17	28.66	2.41	0.104
2	16.70	3.03	0.226	18	12.80	2.58	0.304
3	13.49	2.78	0.374	19	35.59	2.25	0.079
4	31.08	2.76	0.076	20	30.19	2.37	0.147
5	29.35	2.05	0.196	21	26.08	1.99	0.216
6	17.16	2.59	0.304	22	16.98	2.58	0.233
7	26.19	2.14	0.194	23	31.07	1.86	0.217
8	40.72	1.94	0.090	24	29.22	2.30	0.164
9	24.24	1.89	0.204	25	33.83	2.04	0.121
10	30.26	2.96	0.053	26	15.82	2.38	0.329
11	39.35	1.93	0.074	27	26.10	1.99	0.134
12	37.83	1.73	0.155	28	39.09	1.75	0.092
13	21.44	3.11	0.171	29	30.53	2.06	0.151
14	40.51	2.02	0.141	30	17.80	2.55	0.222
15	35.43	2.40	0.018	31	29.22	2.24	0.136
16	16.02	2.19	0.325	32	19.91	2.83	0.062

If the species is eastern hemlock, the equation for height is:

$$HT = 4.5 + 5.3117\left(1.0 - \exp\left(-0.10357 \times DBH\right)\right) \times SI^{0.68454} \times 1.001^{0.7141}$$

where:

> *HT* = tree height
> *DBH* = tree diameter at breast height
> *SI* = species site index

If the species is ponderosa pine and the forest type is 21 the equation for height is:

$$HT = 0.2041 + B_4 \times \left(1.0 - \exp\left(B_5 \times DBH\right)\right)^2$$

where:

$$B_4 = 2.8795 \times (RMDTH)0.0194 + 1.7961$$
$$B_5 = 30.137 \times \left(-0.2774\,(RMDTH - 0.9995)^2\right)$$
$$RMDTH = SI \Big/ \Big(10.0 \wedge \Big(-29.468 \times (1/AGE - 0.02) + 938.97 \times \left((1/AGE)^2 - 0.0004\right)$$
$$-16102.0 \times \left((1/AGE)^3 - 0.000008\right) + 88775.0 \times \left((1/AGE)^4 - 0.00000016\right)\Big)\Big)$$

where:

> *AGE* = current tree age

Bark Ratios

The model calculates bark ratios by calculating diameter inside bark (DIB) from an equation by Clark et al. (1991). It then divides DIB by diameter at breast height (DBH) to determine bark ratio.

$$DIB = b_1 + b_2 \times DBH$$

$$BRATIO = DIB / DBH$$

where:

> *DIB* = diameter, inside bark
> *DBH* = tree diameter at breast height
> *BRATIO* = bark ratio
> b_1 and b_2 = specific species bark coefficients (Table 15)

Table 15. – Bark coefficients for the Southeast Variant

Species	Diameter Inside Bark Coefficients b_1	b_2
RC, JU	-.173	.916
SP	-.441	.930
SA	-.551	.919
SR	-.133	.937
LL	-.459	927
PZ	-.383	.919
PP	-.588	.918
PD	-.513	.902
WP	-.316	.920
LP	-.481	.914
VP	-.311	.950
BY	-.270	.975
PC	-.942	.967
EH	-.049	.923
MP,CM,BE,RM,SV,SM	-.098	.946
OB	-.353	.959
BB,YB,SB,RB	.219	.923
AH	-.130	.971
HI,WH,BH,PH,SL,SH,BI,MH	-.609	.943
PE	-.522	.953
CA,SG,RD,DW,HT,LB,KC,HY,OR MB,WM,RY,OG,RA,NC	-.330	.942
HB	-.183	.958
PS,HL,BN,WN,HH	-.420	.943
AB	-.130	.971
AS,WA	-.487	.938
BA,PA,BS,CT,SD,CW,BP,EC,BT QA,WI,BL,SS	-.251	.943
GA	-.343	.940
SU	-.323	.960
YP	-.230	.924
MG	-.211	.945
MV	-.180	.924
WT	-.381	.973
BG	.199	.889
TS	-.152	.934
SY	-.092	.964
BC	-.130	.941
WO	-.241	.938
SW,BR,CK,LO	-.342	.935
SO	-.409	.946
QN,PN,QI,T0,BJ,NP,QS	-.610	.958
SK	-.421	.930
CB	-.218	.935
LK	-.046	.931
OV	-.380	.944
SN,CO	-.432	.921
WK	-.303	.958
NO	-.346	.970

Species	Diameter Inside Bark Coefficients b_1	b_2
WL	-.397	.948
RO	-.523	.952
PO,DO,DP	-.265	.919
BO	-.707	.948
BK	-.372	.892
BW	-.360	.953
EL,WE,AE,SI,RL,RE	-.420	.963

Relative Density Index

The user can manipulate stocking levels with the THINAUTO keyword. However, there are currently only five stocking categories for the Southeast variant. There are specific stocking charts for shortleaf (SP), slash (SA), longleaf (LL), and loblolly (LP) pines, but not for the remaining species. Therefore, THINAUTO only works for these species. All other species fall into the fifth stocking category. The model uses the following equation to calculate trees per acre in a fully stocked stand for each stocking group:

$$TPA = \left(A_1 \times QMD^2 + A_2 \times QMD + A_3\right) \Big/ \left(0.0054542 \times QMD^2\right)$$

where:

TPA = trees per acre for each stocking category
QMD = stand's quadratic mean diameter
A_1 *to* A_3 = specific species relative density index coefficient (Table 16)

Table 16. – Species Relative Density Index Coefficients for the Southeast Variant

Stocking Group	Relative Density Index Coefficients A_1	A_2	A_3
SP, LP, SA 3 to 8 inches DBH	-1.48	28.37	19.81
SP, LP, SA 8 inches or larger DBH	- .28	10.56	86.00
LL with site index 40 to 60	- .59	15.83	35.86
LL with site index > 60	- .79	22.02	17.95
all other species	- .34	10.72	43.04

The model calculates a relative stand density index by calculating a weighted prediction of trees per acre for each stocking category.

$$STTPA = \left(BA_1 \times TPA_1 + BA_2 \times TPA_2 + BA_3 \times TPA_3 + BA_4 \times TPA_4 + BA_5 \times TPA_5\right) \Big/ TOTBA$$

where:

$STTPA$ = relative density index
BA_n = basal area in each stocking category
TPA_n = trees per acre in each stocking category
$TOTBA$ = total basal area

The Small-tree Model

The small-tree (less than 5.0 inches DBH) model consists of a height and diameter increment model. Transition from the small- to the large-tree model occurs when a tree reaches 5.0 inches DBH or greater. Height increment predictions are weighted over the range of 5.0 to 10.0 inches DBH.

Small-tree Height Growth Model

The user can manipulate potential height growth with the HTGMULT keyword. The height model includes the constant defined by the user with HGTMULT, crown competition, a specific height adjustment factor, and a modifier.

$$POTHTG = CON \times (10.2 - 0.05 \times PTCCF) \times HGADJ$$

where:

$POTHTG$ = potential height growth increment
CON = constant, defined with HGTMULT keyword
$PTCCF$ = point crown competition factor
$HGADJ$ = height adjustment factor

The model calculates the height adjustment factor using a function that uses coefficients specific to species and physiographic area and relates them to site index. Species are pine, oak, or non-oak. There is a different set of coefficients for white pine in the mountain regions, because of more divergent growth rates in the mountains than other pines. Physiographic regions are grouped as flatwoods and bottomlands or as mountains.

$$HGADJ = C_1 + C_2 \times SI$$

where:

$HGADJ$ = height adjustment factor
C_1 and C_2 = coefficients related to species and physiographic region
SI = species site index

Table 17. – Species and Physiographic Region Small-tree Height Growth Coefficients

Physiographic Regions	Species	C_1	C_2
Flatwoods/bottomlands	Pine	-0.078	0.018
(FCP,MCP,HCP,PIE)	Oak	-0.400	0.024
	Non-oak	-0.641	0.029
Mountains	Pine	-0.057	0.014
(VAL,BLU,CMP,LPL)	white pine	-0.524	0.023
	Oak	-0.400	0.024
	Non-oak	-0.359	0.024

The model calculates height growth increment by multiplying potential height by a modifier.

$$HTGR = POTHTG \times XHMOD$$

where:

$HTGR$ = height growth
$POTHTG$ = potential height growth increment
$XHMOD$ =modifier function

The modifier function ($XHMOD$) considers stocking density and crown ratio.

$$XHMOD = \left(1.0 - \exp\left(-2.0 \times \left(SATBA - HBA\right)/HBA\right)\right) \times CRCODE \times 0.12$$

where:

$XHMOD$ =modifier function
$SATBA$ = maximum basal area factor
HBA = stand basal area
$CRCODE$ = crown ratio

Small-tree Diameter Growth Model.

The Southeast variant predicts small-tree diameter increment by first calculating the height of the tree at 5.0 inches DBH (refer to page 10) using the large-tree height increment equations. These equations model the species, forest type, physiographic region, and whether the tree is a pine, oak, or non-oak species. The model then calculates the slope of height over DBH to serve as the diameter increment function for trees less than 5.0 inches DBH.

The Regeneration Establishment Model.

Natural regeneration is not currently available with the Southeast variant. . However, the model does provide for stump sprouting. The only viable method of establishing new trees is artificially in a simulation by using the PLANT or NATURAL keywords. The minimum set of stand management keywords to get a projection from planting trees on bare ground is:

```
ESTAB          1996
PLANT          1996       11       450        100
 or
NATURAL        1996       11       450        100
END
NOTREES
```

Regeneration occurs at the end of the cycle in which it scheduled. Trees are grown from the date of establishment to the end of the cycle. Height growth and diameter growth equations are the same as those used in the small-tree model. However, there is no smoothing of the equations with those in the large-tree model.

Differences between Southeast TWIGS and the Southeast variant:

1. Southeast TWIGS predicts diameter growth on a yearly cycle (a function based on DBH, basal area, average stand diameter, and site index). The Southeast variant predicts diameter growth on a 10-year cycle. Therefore, testing the variant did not replicate exact diameter growth as Southeast TWIGS in all cases. This was also the case for the mortality equation.

2. Southeast TWIGS does not calibrate growth functions to input data, but the Southeast variant does. The Southeast variant re-calibrates diameter growth and/or height growth to fit a site's growth characteristics if stand data includes diameter growth and/or tree height for 5 or more trees of the same species.

3. The Southeast Variant incorporates Stand Density Index driven mortality algorithms; Southeast TWIGS does not.

4. No in-growth is available in the Southeast variant, but bare-ground planting can be done using keywords. The variant can simulate regeneration; Southeast TWIGS does not have this capability.

5. Southeast TWIGS does not include a small tree model. The Forest Management Service Center developed the small tree model of the Southeast Variant.

Model Development and Testing

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Model Testing

Southeast TWIGS is a distance-independent, individual-tree model that computes annual projections. The Southeast variant is also a distance-independent, individual-tree model that computes projections on a ten-year cycle. In tests conducted by members of the Washington Office Forest Management Service Center in Fort Collins, embedding growth relationships from Southeast TWIGS into FVS produced satisfactory results. The tree growth and mortality equations designed to project on an annual basis can also project growth and mortality on a 10-year cycle basis.

For More Information

If you have questions about this overview or want to know more about the Southeast variant, or other FVS variants, contact the Growth and Yield Staff at the following address or phone number.

Forest Management Service Center
Natural Resources Research Center
2150 A Centre Avenue
Fort Collins, CO 80526
Phone: (970) 295-5770 (FVS Hotline)

You can also visit the Service Center's World Wide Web site at "**http://www.fs.fed.us/fmsc**". You can retrieve the executables for FVS from this site. Other world web sites related to FVS are the Pacific Northwest Research Station at "http://faculty.washington.edu/mcgoy" (Stand Visualization System); and, the Forest Health Technology Enterprise Team (FHTET) at http://www.fs.fed.us/foresthealth/technology/fhtet.html (FVS pest extensions).

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Appendix

Appendix 1. Physiographic Regions by State and County

Alabama

Cumberland Mountain Plateau

Blount	Cullman	Dekalb	Jackson	Jefferson
Lawrence	Marshall	Walker	Winston	

Hilly Coastal Plain

Autauga	Barbour	Bibb	Bullock	Butler
Chilton	Choctaw	Clarke	Crenshaw	Dale
Dallas	Elmore	Fayette	Franklin	Greene
Hale	Henry	Lamar	Lowndes	Macon
Marengo	Marion	Monroe	Montgomery	Perry
Pickens	Pike	Russell	Sumter	Tuscaloosa
Wilcox				

Limestone Plateau

Colbert	Lauderdale	Limestone	Madison	Morgan

Middle Coastal Plain

Baldwin	Coffee	Conecuh	Covington	Escambia
Geneva	Houston	Mobile	Washington	

Piedmont

Chambers	Clay	Coosa	Lee	Randolph
Tallapoosa				

Valley and Ridge

Calhoun	Cherokee	Cleburne	Etowah	St. Claire
Shelby	Talladega			

Georgia

Blue Ridge

Fannin	Gilmer	Lumpkin	Rabun	Towns
Union	White			

Cumberland Mountain Plateau

Dade	Walker

Flatlands Coastal Plain

Appling	Atkinson	Bacon	Brantley	Bryan
Camden	Charlton	Chatham	Clinch	Coffee
Echols	Effingham	Evans	Glynn	Jeff Davis
Lanier	Liberty	Long	Lowndes	Mcintosh
Pierce	Ware	Wayne		

Hilly Coastal Plain

Calhoun	Chattahoochee	Clay	Glasock	Houston
Macon	Marion	Peach	Quitman	Randolph
Richmond	Schley	Stewart	Sumter	Taylor
Twiggs	Washington	Webster	Wilkinson	

Middle Coastal Plain

Baker	Ben Hill	Berrien	Bleckley	Brooks
Bulloch	Burke	Candler	Colquitt	Cook
Crisp	Decatur	Dodge	Dooly	Dougherty
Early	Emanuel	Grady	Irwin	Jefferson
Jenkins	Johnson	Laurens	Lee	Miller
Mitchell	Montgomery	Pulaski	Screven	Seminole
Tattnall	Telfair	Terrell	Thomas	Tift
Toombs	Treutlen	Turner	Wheeler	Wilcox
Worth				

Piedmont

Baldwin	Banks	Barrow	Bibb	Butts
Carroll	Cherokee	Clarken	Clayton	Cobb
Columbia	Coweta	Crawford	Dawson	Dekalb
Douglas	Elbert	Fayette	Forsyth	Franklin
Fulton	Greene	Gwinnett	Habersham	Hall
Hancock	Haralson	Harris	Hart	Heard
Henry	Jackson	Jasper	Jones	Lamar
Lincoln	Madison	Mcduffie	Meriwether	Monroe
Morganee	Muscogee	Newton	Oconee	Oglethorpe
Paulding	Pickens	Pike	Putnam	Rockdate
Spaulding	Stephens	Talbot	Taliaferro	Troup
Upson	Walton	Warren	Wilkes	

Valley and Ridge

Bartow	Catoosa	Chattooga	Floyd	Gordon
Murray	Polk	Whitfield		

South Carolina

Blue Ridge

Oconee

Flatlands Coastal Plain

Bamberg	Beaufort	Berkley	Charleston	Colleton
Dillon	Dorchester	Florence	Georgetown	Hampton
Horry	Jasper	Marion	Williamsburg	

Hilly Coastal Plain

Aiken	Chesterfield	Kershaw	Lexington	Richland

Middle Coastal Plain

Allendale	Barnwell	Calhoun	Clarendon	Darlington
Lee	Marlboro	Orangeburg	Sumter	

Piedmont

Abbeville	Anderson	Cherokee	Chester	Edgefield
Fairfield	Greenville	Greenwood	Lancaster	Laurens
McCormick	Newberry	Pickens	Saluda	Spartanburg
Union	York			

Appendix 2. Forest Type Definitions

White Pine - Hemlock (code 4) - Forests in which eastern white pine and hemlock, singly or in combination, comprise a majority of the stocking.

Loblolly Pine Plantation (code 5) - Forests in which loblolly pine was artificially regenerated with acceptable survival and comprises a plurality of the stocking.

Shortleaf Pine Plantation (code 6) - Forests in which shortleaf pine was artificially regenerated with acceptable survival and comprises a plurality of the stocking.

Longleaf Pine Plantation (code 7) - Forests in which longleaf pine was artificially regenerated with acceptable survival and comprises a plurality of the stocking.

Longleaf Pine (code 21) - Forests in which southern yellow pines, singly or in combination, comprise a plurality of the stocking, and in which longleaf pine contributes the most stocking of the pines.

Slash Pine (code 22) - Forests in which southern yellow pines, singly or in combination, comprise a plurality of the stocking, and in which slash pine contributes the most stocking of the pines.

Loblolly Pine (code 31) - Forests in which southern yellow pines, singly or in combination, comprise a plurality of the stocking, and in which loblolly pine contributes the most stocking of the pines.

Shortleaf Pine (code 32) - Forests in which southern yellow pines, singly or in combination, comprise a plurality of the stocking, and in which shortleaf pine contributes the most stocking of the pines.

Virginia Pine (code 33) - Forests in which southern yellow pines, singly or in combination, comprise a plurality of the stocking, and in which Virginia pine contributes the most stocking of the pines.

Redcedar (code 35) Forests in which redcedar comprises a plurality of the stocking.

Pond Pine (code 36) Forests in which southern yellow pines, singly or in combination comprises a plurality of the stocking, and in which pond pine contributes the most stocking of the pines.

Pitch Pine (code 38) - Forests in which southern yellow pines, singly or in combination, comprise a plurality of the stocking, and in which pitch pine contributes the most stocking of the pines.

Oak-Pine (code 40) - Forests in which hardwoods (usually upland oaks) comprise a plurality of the stocking but in which pines comprise 25 to 50 percent of the stocking. Common associates include gum, hickory, and yellow poplar.

Oak-Hickory (code 50) - Forests in which upland oaks or hickory, singly or in combination, comprise a plurality of the stocking, and in which pines comprise 25 to 50 percent of the stocking.

Chestnut Oak (code 52) - Forests in which upland oaks or hickory, singly or in combination, comprise a plurality of the stocking, and in which chestnut oak comprises most of the oak stocking.

Southern Scrub Oak (code 57) - Forests in which any of the various species of scrub oak (e.g., blackjack, turkey, or bluejack), singly or in combination with other scrub oak species, comprises a plurality of the stocking.

Oak-gum-cypress (code 60) - Forests in which bottomland oaks, swamp tupelo, baldcypress, or pondcypress, singly or in combination, comprise a plurality of the stocking.

Elm-ash-cottonwood (code 70) - Forests in which elms, white or green ash, or cottonwood, singly or in combination, comprise a plurality of the stocking.